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Engelmann Spruce Seed Dispersal in the Central Rocky Mountains

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A mathematical expression was developed to estimate Engelmann spruce seed dispersal into clearcut openings. The pattern of seed dispersal is a rapid decline from within the windward stand to the stand edge and beyond into the opening. The amount of seedfall dispersed to the windward stand edge is about 80% of the seedfall under the uncut, windward stand. About 40% of the seedfall under the uncut stand is dispersed as far as 100 feet into the opening, and 10% as far as 300 feet. The initial rapid decline is followed by a gradual leveling-off, with about 1% of the amount of seedfall under uncut stands dispersed as far as 600 feet. The pattern of seedfall is strongly influenced by the direction of the prevailing winds, with little dispersal of seeds from the leeward stand.

Keywords: *Picea engelmannii*, seed dispersal, regeneration

The distance that viable seeds are dispersed is an important factor limiting successful natural regeneration of Engelmann spruce (*Picea engelmannii* Parry ex. Engelm.) in clearcut openings. Proper decisions concerning size of opening that will adequately restock naturally, kind and amount of seedbed preparation, and whether to plant instead of depending upon natural reproduction, require an accurate estimate of effective seed dispersal.

The pattern of spruce seed dispersal into clearcut openings observed in the Rocky Mountains is strongly influenced by the direction of prevailing winds. Sound seedfall generally decreases rapidly from within the stand to the stand edge and beyond into the clearcut opening. About 50% of the amount of seed falling under uncut stands has been dispersed as far as 100 feet into the opening from the windward stand edge, and about 10% dispersed as far as 300 feet. The initial rapid decrease in seedfall is followed by a gradual tailing-off, with less than 5% of the seed falling under uncut stands dispersed as far as 600 feet from the windward source (Alexander 1969, Noble and Ronco 1978, Roe 1967, Roe et al. 1970).

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In the openings observed (200 to 800 feet wide), a U-shaped pattern of seedfall was poorly defined. Minimum seedfall usually occurred about two-thirds of the way across the openings from the windward stand edge. Seedfall then increased, but at the leeward stand edge it was only about 30% of the seedfall along the windward stand edge (Alexander and Shepperd 1983).

Seed dispersal data that are the basis of this study were collected in two, previously reported studies in the central Rocky Mountains that described the detailed methodology (Alexander 1969, Noble and Ronco 1978). Only that detail necessary to understand this study is reported here.

Study Areas and Methods

Seed dispersal data were collected on two areas on the Fraser Experimental Forest from 1956 to 1965, and on five areas on different national forests in Colorado from 1962 to 1971. Seed sources were typical, old-growth Engelmann spruce—subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) stands bordering the windward and leeward edges of clearcut openings 200 to 800 feet wide, oriented with their long axis at right angles to the prevailing winds. Spruces generally accounted for 70% to more than 90% of the basal area of the seed source.

Seed count data were obtained from seed traps placed on transect lines. On two, 400-foot wide, clearcut areas, on the Fraser Experimental Forest, fifteen 0.25 mil-acre seed traps were placed along each of two parallel transect lines, about 132 feet apart, at right angles to the windward stand edge. Seed traps on each transect line were placed at 33-foot intervals, beginning 33 feet into the uncut stand along the windward stand edge and ending 33 feet into the leeward stand edge (fig. 1).

In the other five clearcut areas, 1-foot-square seed traps were placed on transect lines that were parallel to the long axis of the clearing. Ten seed traps were placed on each transect line, at 33-foot intervals. Transect lines were 66 feet apart, with the outer two transect lines 33 feet from the windward and leeward stand edges. One additional transect line was placed 66 feet inside both the uncut windward and leeward stands (fig. 2).

Seed trap contents were collected annually. Sound seed counts (based on cutting tests) were tabulated on each area for each year of observation.

Graphical methods were originally used to estimate seed dispersal into openings in these studies, but mathematical relationships between spruce seedfall under the uncut windward stands and the amount of seed dispersed different distances into cleared openings had been developed elsewhere. White spruce (*Picea glauca* (Moench) Voss) seedfall into a clearcut opening in British Columbia was found to best fit the model $\mathrm{Log}Y = a + bX + cX^2$ (Dobbs 1976). In this model, based on only one year's observation, the regression rate decreased with distance from source, with the result that modest amounts of seedfall extend well into the clearcut opening. Roe (1967) found that Engelmann spruce seedfall into clearcut openings in the northern Rocky Mountains best fit the model $\mathrm{Log}Y = a + bX$. In this model, also based on one year's observation of a bumper seed crop in four different areas, initial seedfall also rapidly decreases as distance from source increases, but it is followed by a gradual leveling-off for a considerable distance into the opening. This "tailing-off" suggests that significant quantities of seed were released during periods of high winds (Dobbs 1976).

Seed dispersal data available from the two studies in the central Rocky Mountains could not be fitted to

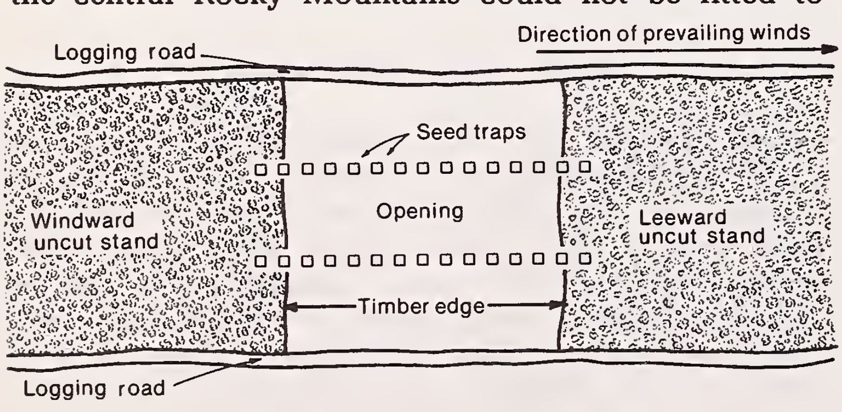

Figure 1.—Location of seed traps in a clearcut opening on the Fraser Experimental Forest, Colo.

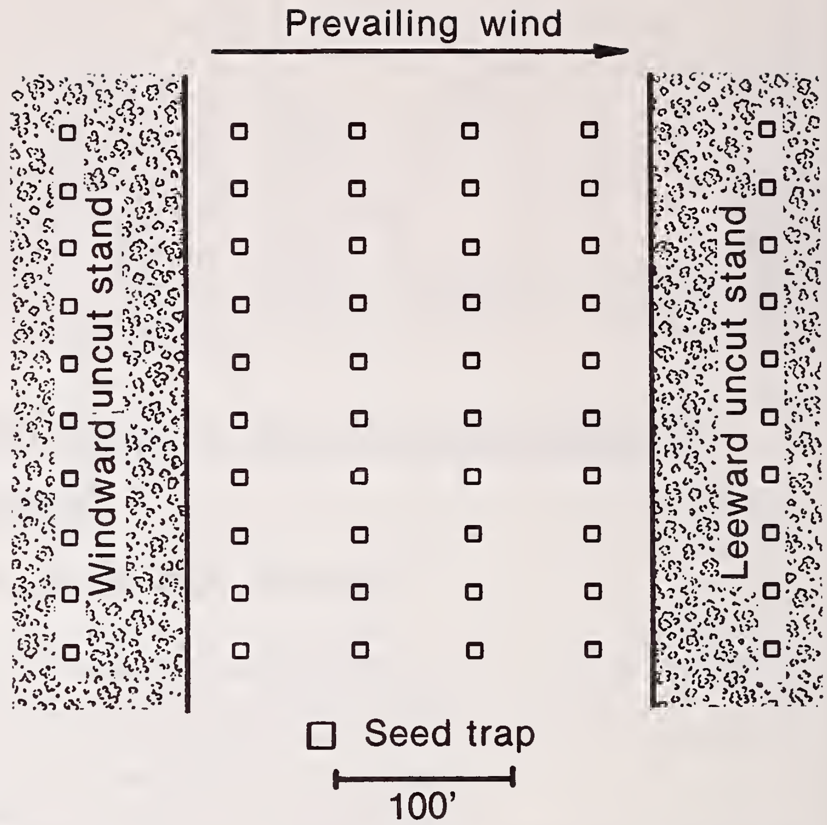

Figure 2.—Location of seed traps in a clearcut opening on the Rio Grande National Forest, Colo. Study areas on the other four national forests were similar except for the width of opening.

either of the above models. The relationship between seedfall and distance from source was then explored by plotting the number of sound seeds falling from the windward stand edge into the opening (for a distance as far as seedfall appeared to be uninfluenced by the leeward stand) against the number of sound seeds falling under the uncut windward stand, which was the source of most of the seedfall in the openings.

Nonlinear least squares regression program was then used to fit the data to the following model:

$$SD = S0 \exp[-b_1(D + 33)^{b_2}] \qquad [1]$$

where SD = Number of sound seeds per acre falling at distance D into the openings (the windward stand edge is denoted by D = 0)

S0 = Number of sound seeds per acre falling under the uncut stand 33 feet from the windward stand edge (denoted by D = − 33)[2]

D = Distance in feet into the opening from windward stand edge

b_1, b_2 = coefficients.

The estimated value of b_2 was nearly 1.0; therefore, the following simplified model was then fit:

$$SD = S0 \exp[-b_1(D + 33)]. \qquad [2]$$

[2]*Although seed traps in uncut stands were placed 66 feet from the stand edge in all study areas except the Fraser Experimental Forest, the number of sound seeds falling under uncut stands was estimated at a distance of 33 feet into the stand from the windward stand edge on all study areas.*

The residual sums of squares of the two models were nearly equal. The resulting equation from the single coefficient model is:

$$SD = S0\,exp(-0.00735D - 0.243) \qquad [3]$$

$R^2 = 0.99$, Sy:x = 37,500 sound seeds per acre.

Although the equation accounts for 99% of the variability centered about the mean, the high standard error of estimate indicates that a large amount of variability is not accounted for by the equation.

Results and Discussion

The precision of equation [3] is about the best that can be expected for estimating seedfall in relation to seed production and distance from source. Because of the variation in seedfall from year to year and from place to place, more data are not likely to reduce the large standard error of estimate.

Equation [3] is useful in estimating potential Engelmann spruce seedfall into openings in the central Rocky Mountains. Figure 3 and table 1 were developed from equation [3] to estimate seedfall into openings for a distance of 600 feet from the windward stand edge. Seed production under uncut stands was set at a range of 50,000 to 1,000,000 sound seeds per acre.

Estimates of seedfall into openings generally follows the pattern previously described for the Rocky Mountains. The amount of seedfall dispersed to the windward stand edge is about 80% of the seedfall under the uncut stand. About 40% of the amount of seedfall under the uncut windward stand is dispersed as far as 100 feet, and about 10% as far as 300 feet. The rapid decline in seedfall then levels off, with about 1% of the amount of seed falling under uncut stands dispersed as far as 600 feet from the windward stand edge. This is in general agreement with the 0.5% to 5% estimates of seedfall at 600 feet from source observed by Roe (1967). There are two important differences, however. Equation [3] is based on estimates of sound seed, not total seedfall, and on two 10-year periods of observation.

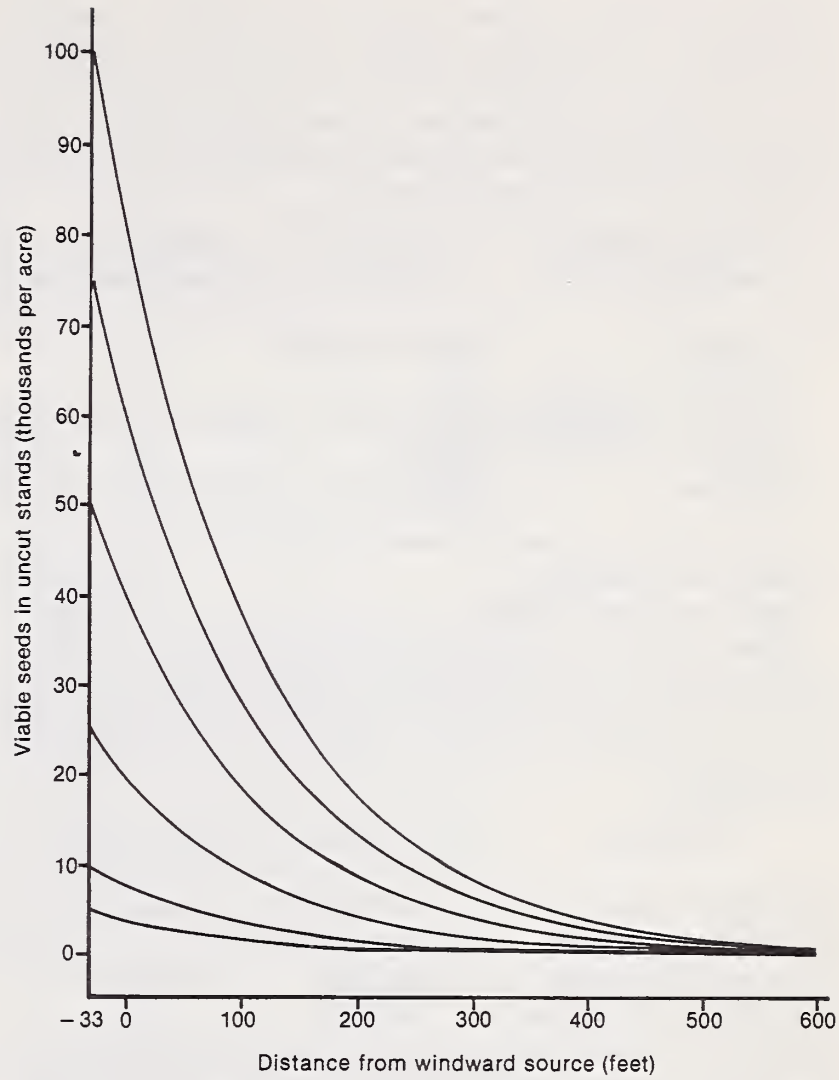

Figure 3.—Seed dispersal in relation to seed production in uncut stands and distance from source (estimated from equation [3]).

Knowledge of the number of seeds that can be dispersed different distances in relation to the amount of seed produced in uncut stands is insufficient. The frequency of good seed crops and estimates of seed to seedling ratios after stocking becomes relatively stable also need to be determined. Both seed production and seedling survival vary considerably, depending upon environmental and biotic factors.

Table 1.—Sound seed dispersal in relation to seed production in uncut stands and distance from source, estimated from equation [3].[1] All data on a per acre basis

Seedfall uncut stands	Distance from windward timber source (feet)												
	0	50	100	150	200	250	300	350	400	450	500	550	600
							(Thousand)						
50	39	27	19	13	9	6	4	3	2	1	1	0.7	0.5
100	78	54	38	26	18	12	9	6	4	3	2	1	1
200	157	109	75	52	36	25	17	12	8	6	4	3	2
300	235	163	113	78	54	37	26	18	12	9	6	4	3
400	314	217	150	104	72	50	35	24	17	11	8	6	4
500	392	272	188	130	90	62	43	30	21	14	10	7	5
600	471	326	226	156	108	75	52	36	25	17	12	8	6
700	549	380	263	182	126	87	61	42	29	20	14	10	7
800	627	434	301	208	144	100	69	48	33	23	16	11	8
900	706	489	338	234	162	112	78	54	37	26	18	12	9
1000	784	543	376	260	180	125	86	60	41	29	20	14	10

[1] $SD = S0\,exp(-0.00735D - 0.243)$

Estimates of the range of seed production possible under uncut, old-growth, spruce-fir stands (fig. 3, table 1) are based on 10 years of observation, at 13 locations, on the Fraser Experimental Forest (Alexander et al. 1982). The amount and frequency of seed production is shown in the following tabulation:

Number of sound seeds per acre	Seed crop rating	Number of years observed
< 50,000	poor to failure	3
50,000 to 100,000	fair	1
100,000 to 250,000	good	2
250,000 to 500,000	heavy	3
> 500,000	bumper	1

In 6 of the 10 years observed, good or better seed crops were produced.

Eight hundred seedlings at age 5 years is a desirable stocking goal for Engelmann spruce (Alexander and Edminster 1980). Numbers of sound seeds required to produce this stocking level for different seedbed conditions on different aspects are shown in the tabulation that follows:

Seedbed	North aspect	South aspect
Scarified-shaded	51,200	545,600
Scarified-unshaded	121,600	∞
Unscarified-shaded	115,200	499,200
Unscarified-unshaded	667,200	∞

These data were developed from long-time studies of seedling survival on the Fraser Experimental Forest.[3] An estimated loss of 50% of sound seeds to seedeaters is built into the tabulation.

Based on the seed dispersal data in table 1, and assuming that, over a 5-year period, the accumulative seed production under uncut windward stands will be at least 1,000,000 sound seeds, the effective seeding distance on scarified-shaded seedbeds on north aspects is about 350 feet from the windward stand edge. Openings 400 to 450 feet wide (assuming an effective seeding distance of 50 to 100 feet from the leeward stand edge) should adequately restock within 5 years. The effective seeding distance on scarified-unshaded and unscarified-shaded seedbeds on the north aspect is about 250 feet from the windward stand edge, with openings 300 to 350 feet wide restocking adequately within 5 years. On unscarified-unshaded seedbeds on the north aspect, and all seedbeds on the south slope, the effective seeding distance is so limited that clearcutting, with adequate natural restocking in a reasonable period of time, is not a viable option.

Management Cautions

Figure 3 and table 1 should be useful in approximating Engelmann spruce seedfall into clearcut openings. However, while the curves developed from equation [3] fit the trends in seed dispersal very well, there is considerable variability around the curves. This means that estimates of seedfall for an individual year at any location may vary considerably from actual seedfall.

The number of viable seeds produced is highly variable from year to year and place to place. Managers need to measure seedfall at a particular location for any given year. As a minimum, a row of at least 10 seed traps about 33 feet apart should be located about 66 feet from the windward stand edge.

Seed: seedling ratios will vary considerably with climatic changes. They represent a period of from 5 to 14 years within one general location, and its local weather conditions.

[3]*Data on file, RWU 1252, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.*

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